



## Summary of Measurement Protocols for Sediment Resuspended from Dredging Operations

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**PURPOSE:** HR Wallingford Ltd. and Dredging Research Ltd. authored *Protocol for the Field Measurement of Sediment Release from Dredgers* in August 2003.<sup>1</sup> This document was made available to the U.S. Army Engineer Research and Development Center (ERDC) through a cooperative research contract. This technical note is intended to summarize the content, layout, and capabilities of the *Protocol* report (also referred to as the TASS Protocol); it does not replace the *Protocol* or serve as a substitute for the *Protocol*. Use of any content herein should be undertaken only after consulting the *Protocol* Report.

Portions of this technical note are taken verbatim from the *Protocol* document. All content within this document is cited to *Protocol for the Field Measurement of Sediment Release from Dredgers* by HR Wallingford Ltd. and Dredging Research Ltd. The *Protocol* is available for download at <http://el.erdcl.usace.army.mil/dots/accord/index.html>.

**BACKGROUND:** VBKO (Vereniging van Waterbouwers in Bagger- Kust en Oeverwerken) of the Netherlands commissioned HR Wallingford Ltd. and Dredging Research Ltd. of the UK to develop preliminary models to predict the rate of release of sediment to the water column from grab, backhoe, bucket ladder, cutterhead, and trailing suction hopper dredges in 1998. It was the intention that, when calibrated by field measurements, these models would be included in a software package (TASS - Turbidity ASsessment Software) that could be used with reasonable confidence to predict sediment release during dredging.

Development of the preliminary source models for sediment resuspension by dredges was completed in early 1999. The research sought to identify all the mechanisms by which sediment is released during dredging and to develop models that predict the rates of release of sediment to the water column. Previous research efforts were used, particularly work undertaken by the U.S. Army Corps of Engineers and several Netherlands organizations including the Dredging Research Association (CSB). A detailed review of published reports on sediment release from dredging operations revealed that field measurement methods were inconsistent and frequently failed to result in the collection of all the data required to assess releases and mechanisms of releases from different types of dredges working in different sediment conditions such as cohesive, noncohesive, and rock materials. The inconsistencies prevented direct and meaningful comparison of the measurements, thus reducing their value.

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<sup>1</sup> Dredging Research Ltd., HR Wallingford. (2003). "Protocol for the field measurement of sediment release from dredgers," <http://el.erdcl.usace.army.mil/dots/accord/index.html>.

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This data vacuum indicated the urgent need for a set of standard field measurement protocols to provide calibration data for the source models. Phase 2 of the TASS project therefore focused on the development of such protocols.

**INTRODUCTION:** In all types of dredging operations, sediment release varies spatially and temporally throughout different stages of the dredging cycle. When coupled with the often discontinuous nature of dredging operations, the resulting rate of sediment release rarely reaches a “steady state.” A large number of measurements are therefore required in order to establish a “characteristic” rate of sediment release and the overall range of release rates for a particular type of operation.

The primary purpose of the TASS sampling protocols is to provide guidance on standard methods of measuring sediment release from dredges, thereby ensuring that the measurements can be used to calibrate the TASS models. If measurements are to be of value for model calibration, it is necessary that they are detailed, accurate, and complete. They must be supported by a comprehensive description of the materials being dredged, the characteristics of the site and dredge, and the manner in which the dredge is operated during the measurements.

For financial or practical reasons, this detailed approach to measurement will not be possible in all circumstances. The TASS team recognizes that although simpler, less costly measurements would not provide all of the detail required for model calibration, they can provide useful ‘second level’ information if undertaken and reported in a standard manner. The TASS protocol therefore includes guidance on the manner in which relatively simple methods of measurement can be applied.

The TASS protocol is specifically not intended to provide guidance for undertaking environmental impact or compliance monitoring during dredging operations. Similarly, the *Protocol* is not intended to provide guidance on measurements designed to calibrate or validate numerical models of sediment transport. However, it is noted that some aspects of the protocol may be of use to those engaged in compliance or environmental monitoring.

**RELEASE MECHANISMS FOR DREDGES:** A section of the Protocol report summarizes release mechanisms for the following dredges:

- Grab (or Bucket) Dredges
- Backhoe Dredges
- Bucket Ladder Dredges
- Cutterhead Dredges
- Trailing Suction Hopper Dredges

Locations of sediment release and the turbidity plumes associated with the respective release methods of each dredge type are discussed.

**PLUME CHARACTERIZATION:** The ideal situation would be to measure the rate of release of sediment at exactly the location(s) where it is released. However, with the single exception of the overflow from trailer dredges, it is not possible to do this for both practical and safety

reasons. In addition, both conventional turbidity meters and acoustic measurements of suspended sediment, on which the TASS Protocol is largely based, are subject to measurement errors when air bubbles are entrained in the water column, which is almost invariably the case close to dredging equipment. An additional complicating factor is the very turbulent zone in the immediate vicinity of the dredging equipment.

As the released sediment is transported out of this turbulent zone by water currents (or the dredging equipment moves away), the behavior of the remaining sediment in suspension (i.e. excluding the large clumps that settle extremely rapidly) becomes more predictable and easier to model. For these reasons, two sources of sediment release have been defined: the “True Source” and the “Practical Source.” The True Source is the actual location where sediment becomes detached from the dredging equipment. It is in an area of high turbulence where the processes of plume development are dominated by ‘fallout’ of large clumps and by the severely hindered settlement of all other particles. This area is defined, for the purposes of this protocol, as the “Dredging Zone.” The Practical Source lies at the edge of the dredging zone where the transport of the resuspended sediment is dominated by the currents of the water column and not by discrete settling or density differences between the plume and the water column. This point may, in some cases, be approximately coincident with the closest point to the dredge at which meaningful measurements can be made. More importantly, it is the point at which subsequent plume behavior becomes reasonably predictable and quantifiable. Figure 1 graphically represents the zones, sources, and associated timescales. Table 1 summarizes the terminology used in Figure 1.

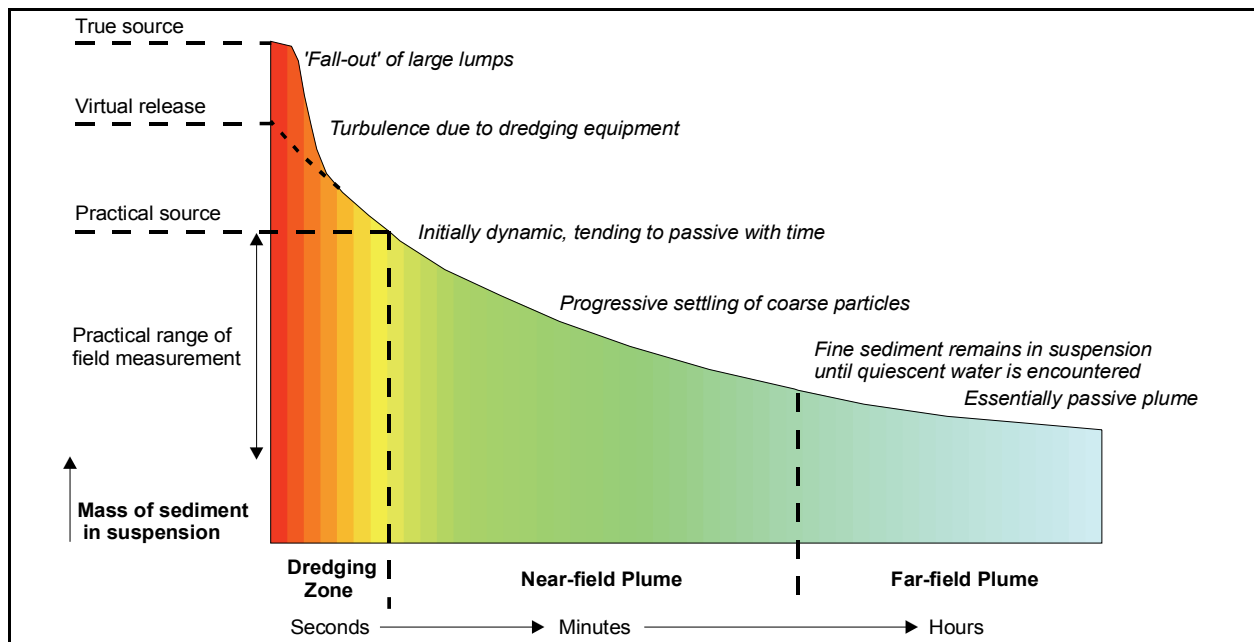


Figure 1. Conceptual breakdown of dredging sources and area

**MEASUREMENT METHODS:** It is possible to identify three classes of measurements that can be used to calibrate the TASS models of the semi-stationary dredges (i.e. grabs, backhoes, bucket ladder dredges and cutterhead dredges). Measurements for the calibration of the trailer model are a special case and are described separately.

<b>Table 1 Summary of Terminology</b>	
True Source	Location(s) of the active part(s) of the dredging unit from which sediment is released.
True Release Rate	The rate at which sediment is released at the <b>True Source</b> (not directly measurable).
Dredging Zone	The zone immediately below and adjacent to the active dredging unit where the material is subjected to mechanically induced turbulence. Large lumps and coarse material settle to bed through clouds of finer suspended material.
Practical Source	The boundary between the Dredging Zone and the <b>Near-Field Plume</b> . In practice this is likely to be the nearest point to the active unit where it is possible to obtain meaningful and relevant measurements. Its location relative to the true source must be known.
Practical Release Rate	The rate at which sediment passes out of the <b>Dredging Zone</b> .
Near-field Plume	The stage of plume development in which the coarser fraction of suspended sediment settles to the bed while being advected by the ambient currents; the initial stages may be dynamic but the plume becomes more passive with time.
Virtual Release Rate	The estimated Release Rate that is back-calculated from the decay curve of the Near-Field Plume.
Far-field Plume	The stage of plume development in which only the fine fraction remains in suspension and is capable of being advected over long distances by the ambient currents as long as the velocity of that current remains above a critical threshold.
Age of Plume	The time that has passed since the sediment first entered the water column at the true source.

**Primary Method.** The recommended approach for obtaining data that can be used for detailed calibration of the TASS models is based on the use of Acoustic Doppler Profilers (ADPs) that have the ability to measure acoustic backscatter intensity from particles suspended in the water, in addition to current speed and direction. The backscatter intensity can, with appropriate calibration and data processing, be used to derive suspended solids concentrations.

There are two ways in which this type of measurement can be undertaken, depending on the type of dredge and site conditions:

- From a boat sailing simple transects downstream of the dredge.
- From an anchored boat as the dredge passes the boat (for cutterhead, bucket ladder, grab, and backhoe dredges).

ADPs are unable to collect data in the near-bed and the near-surface zones. Methods of gathering data in the “blind zones” are given.

**Secondary Methods.** Secondary methods provide sediment flux data but these are not as detailed as those that can be obtained using the primary methods. It is therefore likely that a greater number of measurements will be required in order to determine characteristic rates of sediment release.

The secondary methods use towed arrays of turbidity meters or profiling turbidity meters.

- Towed arrays comprise a series of sensors spaced along a cable that is towed behind the survey boat so that data are collected, as far as possible, throughout the full depth of the water column.
- Profiling turbidity meters are alternately raised and lowered through the full water column as the survey boat passes through the plume.

In order to comply with the requirements of this protocol, current data must also be obtained. These data are preferably obtained by means of an ADP mounted on the survey boat. A less satisfactory approach is to measure the current profile separately using a conventional current meter lowered from the survey boat at a location near the center of the plume.

**Tertiary Methods.** Tertiary methods do not provide data that can be used directly to calibrate the TASS models. The tertiary methods are:

- Far-field profiling in which wide plumes are measured in detail using ADPs, towed arrays, or profiling turbidity meters.
- Near- or far-field single-point measurements using water samplers and/or turbidity meters. Guidance as to the number and spacing of single-point measurements is provided.

Sites where such measurements are undertaken should preferably be in open water as the plumes expand laterally over time, especially in the cases of overflow plumes from trailing suction hopper dredges. The water current must be approximately unidirectional or, if the site is in a tidal area where current directions reverse, the measurements must commence at an early stage of each tide in order to permit sufficient time for the measurements to be carried out before the tide turns.

**Measurement Methods for Trailing Suction Hopper Dredges.** Trailing suction hopper dredges differ from the semi-stationary dredges in several respects that are important to the method of measurement:

- They move relatively quickly over large areas.
- The propellers generate huge amounts of air bubbles; any measurements obtained in propeller wakes using turbidity meters or acoustic methods will not be valid.
- The hopper overflow from trailers also generates air bubbles.

For these reasons, a completely different approach must be used when working with trailers. The Protocol report provides guidance on the measurement of:

- Release through the overflow.
- Release by Lean Mixture OverBoard (LMOB) systems.
- Resuspension by the draghead.
- Far-field plume decay.

**Characteristics of Appropriate Measurement Sites.** If detailed measurements are to be undertaken specifically to calibrate the TASS predictive models, they should preferably be undertaken at sites where conditions are such that accurate identification and quantification of the sediment plume are as easy as possible. The following should be taken into account when selecting sites for such measurements:

- The current regime.
- Saline wedges.
- Water depth.
- The presence of structures (e.g. quay walls) in the measurement area.
- Background sediment concentrations and the effects of other shipping movements.
- Sediment conditions.

The criteria for an ‘ideal site’ are provided in the *Protocol* report.

**Opportunity to Vary the Dredge Configuration and Operation.** When loss measurements are obtained to provide calibration data, certain aspects of dredge configuration and operation should be varied in order to investigate their effects on losses. Table 2 lists some of the parameters that might be varied during calibration measurements. If such variations can be introduced during field measurements, they will provide a greater calibration database.

## SELECTION, CALIBRATION AND USE OF EQUIPMENT

**Survey Boat.** The type of survey boat that is required will depend on the type of equipment to be deployed and on the sea conditions in the survey area. In some cases local regulations and licensing conditions may require certain vessel sizes to be used and, more frequently, the choice of vessel may be limited by availability and cost. It is likely that the boat that is used will represent a compromise solution. Guidance is provided in the *Protocol* report.

**Positioning Equipment.** Differential global positioning system (DGPS) equipment is necessary to satisfy the TASS protocol. Guidance for the positioning of DGPS antennas on both the survey boat and dredge are provided to ensure accurate knowledge of dredge position, sediment release position, survey boat position, and survey boat speed and heading.

**Acoustic Doppler Profilers.** Selection criteria are given based on:

- Ability to measure and record the backscatter intensity from particles suspended in the water column.
- ‘Bottom track’ facility (if the ADP is being used for solids flux calculations).
- Nominal profiling range.

<b>Table 2 Dredging Parameters That Could Be Varied During Loss Measurements</b>	
<b>Dredge</b>	<b>Operating parameters</b>
Grab	<ul style="list-style-type: none"> <li>• Using open and closed grabs</li> <li>• Using different sizes of grab</li> <li>• Varying the grab hoisting speed</li> <li>• Varying the slewing speed</li> </ul>
Backhoe	<ul style="list-style-type: none"> <li>• Using open and closed buckets</li> <li>• Using different sizes of bucket</li> <li>• Varying the cycle time</li> <li>• Varying the slewing speed</li> </ul>
Bucket	<ul style="list-style-type: none"> <li>• Varying the cut height and step length</li> <li>• Varying the swing speed</li> <li>• Varying the bucket speed</li> </ul>
Cutterhead	<ul style="list-style-type: none"> <li>• Varying the cut height and step length</li> <li>• Using different cutterhead rotation speeds</li> <li>• Using different swing speeds</li> <li>• Varying the suction velocity</li> <li>• Varying the cutterhead type (teeth, shroud, and shape)</li> <li>• Varying the ladder length</li> <li>• Varying the direction of cut</li> </ul>
Trailing suction hopper	<ul style="list-style-type: none"> <li>• Changing the suction pipe velocity</li> <li>• Varying the trailing speed</li> <li>• Loading with one suction pipe instead of two</li> <li>• Allowing overflow, not allowing overflow</li> <li>• Varying the draghead</li> <li>• Varying the depth of cut</li> </ul>

Further guidance is given on:

- ADP mounting options.
- Sailing speed and noise effects.
- ADP power supplies.
- External compasses (no bottom track ability).
- Temperature and salinity measurements.
- ADP calibration and data processing.

The derivation of solids concentration values is complex and requires specialized software. Readers of the *Protocol* are advised to consult a specialist firm experienced in these matters, if the ADP technique is to be used.



**Turbidity Meters.** There are two main requirements with respect to the selection of turbidity meters:

- They must be capable of measuring in the full range of expected sediment concentrations.
- They must not be affected by ambient light.

Calibration of turbidity meters is discussed in the *Protocol* report, including the selection of water sampling equipment that is necessary for calibration. It is noted that turbidity meters must be calibrated in such a manner that variations with the age of the plume can be established.

**Dredge Instrumentation.** In addition to knowing the position of the sources of sediment release, it is essential to be able to relate loss measurements to the manner of operation of the dredge. The dredge should be fitted with instrumentation that, at least, permits the accurate observation and manual recording of its position, the dredging depth, and the main operating parameters. Ideally, the instrumentation will be capable of recording these (time-stamped) data for later analysis.

**Measurement Time Synchronization.** It is essential that all measurements are accurately time-synchronized. For very simple measurements (e.g. single-point measurements of solids concentration), this may require only synchronization of the watches used by the observer on board the dredge and the crew on board the survey boat. For more complex measurements, such as measurement of sediment flux using a combination of acoustic and conventional methods, it will be necessary to apply a more complex approach to synchronization.

**Measurement Cycles.** Measurements should generally be undertaken on a continuous basis throughout the measurement period. However, when analyzing and reporting the observations, they should be divided into data sets that represent, as near as is possible, periods during which ground conditions, water depths, and the manner of operation of the dredge were consistent.

**Air or Gas Bubbles.** Both ADPs and turbidity meters are affected by the presence of air or gas bubbles entrained in the water column. It takes on the order of a minute for these bubbles to dissipate. It is essential, especially when working close to the dredging plant, that every effort is made to establish whether the data are corrupted by bubbles and to modify the measurement methods to avoid such contamination.

**Video Cameras.** Time-stamped video records of the dredging operation can be invaluable. This is particularly the case when working with backhoes and grabs where the on-board observer has to record large quantities of data about the timing of each cycle. A video camera provides a useful backup to these observations. The video camera clock should be synchronized with GPS time before each set of observations.

**SUPPORTING DATA REQUIREMENTS:** Measurements of sediment release have little value unless they can be related directly to the type and size of dredge, its manner of operation, and the site and sediment conditions. The accurate recording of these data is therefore as important as the accurate measurement of the losses. The following data supporting data requirements are explained and described in detail in the *Protocol* report:

- Site morphology and bathymetry.
- Hydrodynamic and water quality conditions.
- Sediment and bed conditions.
- Dredging equipment characteristics.
- Dredging activity.
- Dredged volumes.

**SEDIMENT FLUX CALCULATION PROCEDURES:** The Protocol report includes a detailed section on sediment flux calculation procedures for the different methods of measurement.

**REPORTING RECOMMENDATIONS:** It is often the case that the value of measurement data is reduced because it is reported inadequately. All information that is relevant to understanding the manner in which the data were obtained, the nature of the dredging operation to which they relate, and uncertainties in the accuracy of the basic observations and the flux estimates must be presented in the report. The recommended general format of the report is described below:

- Executive Summary.
- Introduction.
- Dredging Operations.
- Methods of Measurement and Data Analysis.
- Equipment Calibration and Test Procedures.
- Results.
- Data Files.

**SUMMARY:** Protocol for the Field Measurement of Sediment Release from Dredgers was authored by HR Wallingford Ltd. and Dredging Research Ltd. (August 2003). This technical note summarizes the content, layout, and capabilities of that report, allowing more rapid familiarity with the original document. Information for obtaining the original document is provided herein.

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